Pacific Northwest Forest and Range Experiment Station

Forest Service RESEARCH NOTE

PNW-82 *July 1968*

CAN THINNING SLASH CAUSE A NITROGEN DEFICIENCY IN PUMICE SOILS OF CENTRAL OREGON?

by

P. H. Cochran, *Soil Scientist*

ABSTRACT

Decomposition of thinning slash deposited on the soil surface should have no direct adverse effect on the soil nitrogen available to higher plants in the pumice soil region. Decomposition of roots of cut trees would immobilize nitrogen in the soil immediately adjacent to the root during the decomposition period, which appears to be short for the smaller roots. However, these dead roots no longer compete for soil nitrogen in unexploited soil zones. Thus, nitrogen available for individual trees may be increased by thinning. If chipped slash is mechanically incorporated into the soil, a temporary nitrogen deficiency is likely, particularly in nonpumice soils. This deficiency can be prevented by fertilization.

INTRODUCTION

The question posed by the title deserves comment at this time for several related reasons. Thinning stands to wide spacings, in studies now underway in central Oregon, have resulted in large increases in individual lodgepole and ponderosa pine tree growth. In some of these studies, the slash was removed after thinning. In contrast, slash is not removed in the thinning operations on National Forest lands in central Oregon. Although comparative data have not

been collected, some foresters feel that the thinning on their districts has not resulted in the growth increases which the thinning studies indicate are possible. Nitrogen deficiencies during slash decomposition have been suggested as a reason for this possible discrepancy.

The incorporation of organic material with a wide C:N ratio does result in decreased nitrogen availability to higher plants during the decomposition period if a large portion of the carbon is readily available to the microbial population. The addition of the readily available carbon provides an energy source for the microbial population. If other environmental factors are favorable, the numbers of microbes increase and their activity becomes so intense that much of the soil nitrogen which would otherwise be available to higher plants is utilized in the formation of microbial protoplasm. As the added carbon is microbially attacked, some is given off as CO_2 and the C:N ratio gradually narrows. As the C:N ratio narrows, the microbial activity subsides and the nitrogen released for higher plants increases to its former level. The effects of adding the organic material should be expected to last longer in the pumice soil region; there, low soil temperatures and periodically dry surface soil horizons retard the decomposition process. When the meadows in the region were homesteaded in the 1920's and 1930's, rye was a principal crop. In order for a rye crop to be grown, the land had to be fallow for at least 1 year after plowing.[1/] Therefore, nitrogen was probably not available for the growth of higher plants immediately after the native meadow vegetation was turned under. A 1-year fallow period was necessary before the C:N ratio of the added residue narrowed and the microbial activity slackened, allowing the release of N for uptake by higher plants.

THE EFFECT OF C:N RATIOS OF INCORPORATED RESIDUES ON NITROGEN IMMOBILIZATION AND MINERALIZATION

Immobilization is a mechanism by which micro-organisms reduce the quantity of nutrients available to plants in the soil; nitrogen mineralization is the conversion of organic nitrogen to the inorganic state (*1*).[2/]

In an undisturbed soil, the microbial activity in a given season and the C:N ratio are fairly stable. As plant, animal, and microbial residues are gradually added, microbes attack and decompose all but a small amount of very resistant material (primarily lignin and some protein) which is added to the humus complex. The humus complex, in turn, is continually being attacked by the microbial population, and

---

1/ Personal communication, Archie Deadmond, Silver Lake, Oregon.

2/ Italic numbers in parentheses refer to Literature Cited, p. 11.

the amount of nitrogen, carbon, and other nutrients added through decomposition of fresh animal, plant, and microbial residue balances the amount of these materials released from the humus by slow and continual microbial decomposition. All of the carbon and nitrogen in the residue either passes through the tissue of the living microbes (after which some nitrogen may be mineralized or some carbon released as CO_2) or these elements are added to the humus complex to be eventually released by decompostition. The overall results of these processes are that the additions and losses of C, N, and other nutrients are nearly in balance and that the C:P, C:K, and C:S ratios, as well as the C:N ratio, are nearly constant.

The C:N ratio of a soil is a weighted average of the C:N ratio of the living microbial tissue (4:1 to 9:1) and the other organic material, primarily humus, which has a wider C:N ratio (1). The C:N ratios of most arable soils vary from 8:1 to 15:1 (4).

Since C:N ratios for given soils are a result of a dynamic equilibrium, as decomposition of added organic material with a wide C:N ratio occurs, the C:N ratio of the added residue is gradually narrowed. After decomposition, the original C:N ratio of the soil is maintained. During decomposition, the microbial population assimilates a portion of the added carbon for generation of new protoplasm, and there is also a concomitant uptake of N and other nutrients. The rest of the carbon is liberated as CO_2 or is added in organic form to the humus complex to be more slowly decomposed later.

The above dicussion can be illustrated by the following hypothetical problem:

Suppose that 2,000 pounds of wheat straw (0.5 percent N and 40 percent C) are added to a soil having a C:N ratio of 15:1. This carbon is readily available, and it is reasonable to assume that the microbial population will release 66 percent of the added carbon as CO_2, and that the other 34 percent will be added to the organic carbon already in the soil (1, p. 40). In this example, 272 pounds of carbon (2,000 pounds x 0.40 x 0.34) will be added. In order for the microbial population to carry out the decomposition process and in order for the C:N ratio to remain stable, 18.1 pounds of nitrogen (N:272 = 1.15; N = 18.1) must be tied up either by the microbial population or with the slowly decomposible portions of the straw which are added to the humus without being passed through microbial tissue. The nitrogen content of the straw is only 10 pounds (0.005 x 2,000), so an additional 8.1 pounds (18.1 - 10) must be supplied for the decomposition process. Therefore, during decomposition, the amount of nitrogen available for higher plant uptake will be reduced by 8.1 pounds. Similar calculations can be carried out to show that incorporation of a material with a narrow C:N ratio, such as alfalfa, would result in an increase in the amount of nitrogen available for higher plants.

THE EFFECT OF SLASH ON NITROGEN IMMOBILIZATION AND MINERALIZATION

When a stand is thinned and the slash is left on the ground, the microclimate is considerably modified. Briefly, soil temperatures under slash are cooler and undergo less variation than if slash is removed. Also, evaporation from slash-covered soils is less than from areas where slash is removed. The resulting effects on tree growth are impossible to assess. In a corn mulching study, conducted at various locations throughout the cornbelt, mulching decreased soil temperatures in the northern portion of the cornbelt and thus decreased corn growth there (6).

Data now available for pumice soils do allow some conclusions concerning the effect of slash on nitrogen immobilization and mineralization for the pumice region. The C:N ratio for the combined A1 and AC horizons of a Lapine pumice soil is a surprisingly high 22.8:1.[3/] If we assume bulk densities of 0.7 g./cm.^{3} and 0.6 g./cm.^{3} and horizon depths of 0-2 inches and 2-10 inches for the A1 and AC horizons, respectively, and use the N content data given by Dyrness,[4/] the value of 824 pounds of nitrogen per acre can be calculated for a pumice soil.

For woody plants in general, the C:N ratios for wood, bark, and foliage are about 500:1 or more, 300:1, and 50:1 to 25:1, respectively.[5/] In the heaviest thinning in central Oregon, more than 58,500 pounds of slash per acre were left on the ground.[6/] Obviously, if all of this material were ground up and incorporated into the soil profile, serious nitrogen deficiencies would result if all of the incorporated carbon was readily utilized by the microbial population. However, coniferous wood, bark, and sawdust contain 60 to 70 percent of inherently resistant lignocellulose. This substance decomposes so slowly that resistance to attack rather than available nitrogen controls its rate of decomposition (3). Further, this material is not ground up, is not incorporated into the soil profile immediately, and, from some indications, a large part is never incorporated.

3/ Dyrness, Christen Theodore. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. 217 pp. 1960. (Unpublished Ph. D. thesis, on file at Oreg. State Univ., Corvallis.

4/ See footnote 3.

5/ Leaf, Albert L. Wood waste: a valuable soil amendment. 8 pp. 1962. (Unpublished report on file at Silvicult. Dep., State Univ. Coll. Forest. at Syracuse.)

6/ This thinning was carried out in 1965 in connection with a levels-of-growing-stock study. The weight was estimated by the method given by Fahnestock (5).

Fahnestock (5) found that the fine twigs and all the larger branches of pine slash were still intact at the end of a 3-year study period. He also found that foliage fell gradually from the slash of ponderosa and lodgepole pine, and that, 3 years after cutting, supported foliage still was an important fuel component. Observations of thinnings conducted on the Deschutes National Forest show that limbs of 9-year-old ponderosa pine slash in the Green Mountain area are still intact and appear no more decomposed than comparable dead limbs on living trees. Needles were off the slash, but many were still on top of the ground unincorporated into the soil profile. Other observations of thinnings in central Oregon indicate that needles stay on the slash for at least 3 years but are off the slash and on the ground at the end of the 5th or 6th year and that slash limbs are still above ground at the end of 9 years. Therefore, in the first decade after thinning, only a portion of the pine needles become incorporated into the soil profile. The question now becomes: What is the effect of needle addition on nitrogen availability to higher plants?

In the heavy levels-of-growing-stock thinning, we estimate, by use of Fahnestock's (5) data, that there are 12,400 pounds of foliage included in the 58,500 pounds of slash per acre. The nitrogen content of ponderosa pine foliage has been shown to vary from 0.51 percent for 350-year-old stands to 0.79 percent for 100-year-old stands (9). The carbon content of this material is about 40 percent.[7/] If we used a conservative estimate of 0.65 percent N for the foliar content of the levels-of-growing-stock study slash, the C:N ratio of the foliage would be approximately 62:1. If we assume that all 12,400 pounds of foliage were incorporated into a profile where the C:N ratio of the soil is 22.8:1, the amount of N mineralized or immobilized during the decomposition can be calculated by use of the valid assumption (1, p. 40) that 66 percent of the added carbon is given off as CO_2. These calculations follow:

(1) Amount of carbon added in the foliage:
$12{,}400 \times 0.40 = 4{,}960$ pounds per acre

(2) Amount of carbon retained after decomposition of foliage:
$4{,}960 \times (1.00 - 0.66) = 1{,}686$ pounds per acre

(3) Amount of nitrogen which must be used during decomposition:
$1{:}22.8 = N{:}1{,}686$
$N = 74$ pounds per acre

7/ C. T. Youngberg, professor of forest soils, Oregon State University, personal communication.

(4) Amount of nitrogen added in the foliage:

12,400 x 0.0065 = 80.6 pounds per acre

(5) Since the amount of nitrogen added in the foliage is greater than the amount necessary for decomposition, the amount of N mineralized or made available to higher plants is:

80.6 - 74.0 = 6.6 pounds per acre

From observations of slash left by thinning of ponderosa pine in the Deschutes National Forest since 1958 and from the above calculations, the following conclusion has been made. If there is a difference in growth between the thinning studies where slash has been removed and in other thinning operations where slash has not been removed, it is not due to nitrogen immobilization resulting from slash decomposition in the pumice region. Interestingly, in agreement with the above calculations, Stone and Will (8) concluded that some of the nitrogen in the litter and slash from Monterey pine becomes available for use of pine seedlings in some areas of New Zealand.

What would be the effect if this amount of slash were added to a soil with a narrower C:N ratio of 10:1? The amount of nitrogen which would be necessarily tied up during the decomposition period would be:

1:10 = N:1,686
N = 169 pounds per acre

If all of the foliage were immediately incorporated into this soil, the amount of nitrogen in the added foliage would not be great enough to allow for decomposition without the immobilization of 88.4 pounds of nitrogen per acre (169 pounds N per acre - 80.6 pounds N per acre = 88.4 pounds N per acre). However, the period of immobilization would be brief because the high soil nitrogen content would permit a rapid buildup of an active microbial population, which would soon decompose the foliage. After a brief decomposition period, there would be an increase of 88.4 pounds of nitrogen per acre in the soil minus the amount of nitrogen which had escaped from the profile by leaching or volatilization during the decomposition period. In short, there would be some immobilization during a brief decomposition period; then an increase in nitrogen for the growth of higher plants is likely.

In the forested stand, the needles are slowly incorporated into the soil profile by small macroanimals such as small mammals, insects, slugs, snails, mites, and earthworms (4). Thus, the decomposition period is lengthened, and portions of the added foliage are decomposed before other portions are incorporated into the soil profile. Therefore, the amount of nitrogen immobilized at any given time would be small in comparison with the total nitrogen in the soil. Detailed information about the carbon and nitrogen contents of the soils and

of the foliage and about the length of the decomposition period is necessary before a specific statement can be made about the nitrogen immobilized in any given thinned stand.

THE EFFECT OF ROOTS OF CUT TREES ON NITROGEN IMMOBILIZATION

The soil environment of a zone 5 to 20 mm. from the root surface is unique. Sloughed-off root cells provide material for microbial development, and the active root exudes substances which usually enhance microbial activity (7). The carbon dioxide and oxygen concentrations differ considerably from those in the soil some distance from the root. This zone, which is under the influence of the plant roots, is called the rhizosphere (1, 7).

The microbial activity within the rhizosphere is maintained at a more constant and intense level than in the other soil regions (1, 7), and the number of organisms may be 10 to 100 times as great as elsewhere in the soil (4). The individual organisms are also much more active biochemically than organisms from other parts of the soil (1, p. 446). Because of the competitive stress due to the large, active, fast-growing population, much of the nitrogen in the rhizosphere is immobilized at any given time, but the rate of turnover is rapid (1, p. 451).

When a root dies, an active microbial population is present, so the root immediately begins to decompose. Observations of thinned stands in the pumice soil region indicate that the largest roots of trees up to approximately 5 inches in d.b.h. decompose in about 5 years. Smaller roots decompose much faster. The decomposition of the root tissue occurs in much the same manner as decomposition of incorporated foliage. Carbon from the root tissue is utilized by the microbes, and a portion is released as CO_2. The nitrogen is tied up by succeeding generations of microbes; these continually attack the roots until the supply of readily available carbon is exhausted and only the very slowly decomposable material is left. By then the activity of the microbial population has receded to a level comparable with its activity in other parts of the soil, and a portion of the nitrogen in the original rhizosphere becomes available for uptake by roots of other plants which invade the area.

The uptake of nitrogen and other nutrients occurs mostly through young, nonsuberized roots continually being produced when soil temperatures are above a certain critical level. These roots either move into unoccupied soil areas to take up nitrogen, primarily as NO_3- or NH_4+, or these ions flow to the absorbing root surfaces in the soil solution. Since most of nitrogen in the rhizosphere of a living root is immobilized at any one time (1, p. 451), the death of this root

would not necessarily result in a decrease in nitrogen available to the remaining live roots. During the decomposition period of the dead roots, the nitrogen in the rhizosphere is completely tied up by the microbial population. However, the rhizosphere area of the dead root system continually shrinks as the roots decompose, and in addition, these dead roots are no longer extending into unoccupied soil to compete with the remaining live roots. As a result, the roots of trees left in a thinned stand may be able to take up more nitrogen than before the stand was thinned.

One test of this hypothesis would be to analyze the foliage of thinned and unthinned stands. To the author's knowledge, this has not been done for any western conifer. Boggess (2) studied the influence of thinning on the foliar nitrogen content of shortleaf pine in southern Illinois. He found significant increases in foliar nitrogen for trees on plots which had been thinned 2 to 3 years earlier than for those on unthinned plots. The increases in foliar nitrogen on the thinned plots were attributed to more rapid breakdown of litter caused by increased sunlight reaching the forest floor and to the availability of more nitrogen per tree when more than one-third of the basal area was removed.

THE EFFECT OF CHIPPED SLASH ON NITROGEN IMMOBILIZATION

Thinning slash along roadsides and in or near recreational areas is often chipped and left on the surface of the soil. As long as the material is left on the surface, it will have little or no direct effect on the availability of nitrogen to higher plants. No data are now available on the rate of incorporation and decomposition of this material. Observations on the Deschutes National Forest suggest that larger wood chips remain on the surface for several years. These large chips, like the larger log and limb material, are invaded by fungi and other organisms and may be decomposed primarily above ground.

In many potential recreational areas, it may become desirable to incorporate this chipped material into the soil by rototilling or by some other method and to establish an attractive vegetative cover. In this case, nitrogen deficiency for higher plants is possible, and applications of fertilizer nitrogen may be desirable.

As mentioned previously, if all the carbon in the incorporated slash was readily available for microbial utilization, the nitrogen deficiency would be serious. However, unlike foliage carbon and nitrogen, much of the nitrogen and carbon in bark and wood is not readily available. Conifer wood bark and sawdust are so resistant to attack that this resistance rather than available nitrogen controls

the rate of decomposition (3). According to Bollen,[8] ponderosa pine sawdust contains 50 percent carbon and 0.05 percent nitrogen, but 1 ton of this material contains only 50 to 100 pounds of available carbon and almost no nitrogen. Bollen has found that 3 to 5 pounds of elemental nitrogen for each ton of dry sawdust will suffice for initial decomposition. After the initial decomposition, the more resistant carbon will decompose more slowly, and succeeding generations of microorganisms can reuse the same nitrogen. This prevents appreciable amounts of nitrogen from being immobilized by the microbial population at any one time. Greater nitrogen additions may function directly as a fertilizer, but such additions will not appreciably hasten decomposition of the sawdust (3).

Fahnestock's data (5) show that approximately 80 percent of ponderosa and lodgepole pine slash is composed of bark and wood. Using the results of Bollen, 4 pounds of nitrogen per ton of dry incorporated slash

(5 pounds per ton of sawdust x 0.80 = 4 pounds per ton of slash),

should prevent nitrogen deficiency for the higher plants during the decomposition of the wood and bark. Many of the chips are large and are therefore even less subject to rapid decomposition than sawdust, and a portion of the foliar nitrogen would become available in pumice soils. For these two reasons, 4 pounds of nitrogen per ton of dry incorporated slash should prevent temporary nitrogen starvation and should even allow some of the added nitrogen to act directly as a fertilizer.

In nonpumice soils, where incorporated foliar decomposition requires additional nitrogen, a rough rule of thumb can be used in calculating the amount of nitrogen which should be added with the incorporated chipped slash. This rule[9] states that the C:N ratio of incorporated foliage should be reduced to 30:1 by adding nitrogen to prevent a temporary nitrogen deficiency. The foliar C:N ratio is about 62:1. One ton of slash contains about 400 pounds of foliage (2,000 pounds x (1.00 - 0.80). The foliar carbon content of this amount is 160 pounds (400 pounds x 0.40), and the foliar nitrogen content is 6.5 pounds (62:1 = 400 pounds:N pounds). The amount of nitrogen that must be added to reduce the foliar C:N ratio to 30:1 is calculated as follows:

8/ Bollen, W. B. Artificial manure and composts--proportions of nitrogen and other additions per ton of dry material. (Unpublished, undated report on file at Microbiology Department, Oregon State University.)

9/ See footnote 5.

(1) Amount of nitrogen necessary for the 30:1 ratio:

400:N = 30:1
N = 13.3 pounds

(2) Amount of nitrogen which must be added to balance the readily available foliar carbon equals the amount needed minus the amount present in the foliage:

13.3 pounds - 6.5 pounds = 6.8 pounds

For nonpumice soils, the total amount of nitrogen to add to prevent nitrogen immobilization due to incorporated chipped slash would equal:

1. the amount necessary to provide for utilization of the readily available carbon in the wood and bark (4 pounds N per dry ton;

2. plus the amount necessary for foliar decomposition (6.8 pounds N per ton) or 10.8 pounds of nitrogen per ton of dry slash.

SUMMARY

If differences in growth have occurred in thinning studies where slash has been removed and in other thinning operations where slash has not been removed, it is not due to nitrogen immobilization resulting from slash decomposition in the pumice soil region. In other soils, decomposition of aboveground slash may result in some small immobilization, but data are not available to confirm this.

The microbial population associated with decomposing roots of dead trees immobilize nitrogen in the soil zone immediately adjacent to the roots. The roots of the trees that are left have less competition for unexploited soil, and the amount of nitrogen available for individual trees may be increased by thinning. Foliar analysis data for thinned and unthinned stands must be collected so this phenomenon can be fully understood.

Chipped slash, if incorporated into the soil, could temporarily deprive plants of nitrogen, particularly in nonpumice soils. Calculations are presented to show the amount of nitrogen to add to prevent this temporary deficiency.

LITERATURE CITED

1. Alexander, Martin.
   1961. Introduction to soil microbiology. 472 pp. New York: John Wiley and Sons.

2. Boggess, W. R.
   1959. Foliar nitrogen content of shortleaf pine as influenced by thinning. Univ. Ill. Agr. Exp. Sta., Urbana. Forestry Note No. 80, 2 pp.

3. Bollen, Walter B.
   1953. Mulches and soil conditioners--carbon and nitrogen in farm and forest products. Agr. & Food Chem. 1: 379-381.

4. Buckman, Harry O., and Brady, Nyle C.
   1962. The nature and properties of soils. 567 pp. New York: The MacMillan Co.

5. Fahnestock, George R.
   1960. Logging slash flammability. U.S.D.A. Forest Serv; Intermountain Forest & Range Exp. Sta. Res. Pap. 58, 67 pp.

6. Larson, W. E., Burrows, W. C., and Willis, W. O.
   1960. Soil temperature, soil moisture, and corn growth as influenced by mulches of crop residues. _7th Int. Congr. Soil Sci._ (Madison) I: 29, 629-637.

7. Parkinson, D.
   1967. Soil micro-organisms and plant roots. Pp. 449-478. _In_ Soil biology. Ed. by A. Burges and F. Raw. London and New York: Acad. Press. 532 pp.

8. Stone, E. L., and Will, G. M.
   1963. Nitrogen deficiency of second generation radiata pine in New Zealand. Pp. 117-139. In Forest-soil relationships in North America. Ed. by C. T. Youngberg. 532 pp. Oreg. State Univ. Press, Corvallis.

9. Tarrant, R. F., Isaac, L. A., and Chandler, R. F.
   1951. Observations on litter fall and foliage nutrient content of some Pacific Northwest tree species. J. Forest. 49: 914-915.